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TABLES FOR DETERMINATION OF FLOW VARIABLE GRADIENTS BEHIND CURVED SHOCK WAVES

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BALLISTIC RESEARCH LABORATORIES

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A B E R D E E N   P R O V I N G   G R O U N D ,   M A R Y L A N D

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ABSTRACT

The shock wave relations and the equations of isoenergetic two-dimensional or axisymmetric flows can be combined to yield expressions for various useful quantities behind a shock wave if the curvature is known in addition to the position and slope. Tables are presented here of computations, for $\gamma = 1.4$, of seven functions of Mach number and shock wave slope, from which the following are easily computed: 1) streamline curvature, 2) velocity gradient along streamline, 3) angle between streamline and density contour, and 4) angle between streamline and Mach number contour. In addition, the Mach number and angle of inclination of streamline are listed. A Mach number range from 1.1 to 10 is covered by these computations.

A derivation of the shock gradient functions is presented; and several applications of the calculations are given, including a set of tables for determining the slope of the sonic line.

SYMBOLS

(x, r)	- rectangular coordinates
(n, s)	- natural coordinates normal and tangential respectively to streamline
A	$= (\cos^2 \beta + g^2 \sin^2 \beta)^{1/2}$
a	- speed of sound $= (\partial p/\partial \rho)^{1/2}$
$F_1, F_2 \ldots F_7$	- shock gradient functions
g	- inverse of density ratio across shock $= \rho_1/\rho$
h	- enthalpy
K_s	- curvature of shock wave
K_ψ	- curvature of streamline
ℓ	- inverse of pressure ratio across shock $= p_1/p$
M	- Mach number
m	$= M_1 \sin \beta$
p	- pressure
q	- velocity
R	- ratio of stagnation densities across shock
S	- entropy
T	- temperature
β	- angle between shock wave and x-axis
γ	- ratio of specific heats (= 1.4 for air)
ϵ	- 0 for 2-dimensional flow 1 for axisymmetric flow
ζ	- angle between streamline and line of constant density
θ	- angle between streamline and x-axis
ξ	- angle between streamline and line of constant Mach number

ρ - density

σ - arc length along shock wave

Subscripts

1 - free stream

t - stagnation

I. INTRODUCTION

The problem of determining the gradients of the flow variables behind a shock wave in isoenergetic two-dimensional flow has been considered by several investigators[1,2,3]. These gradients are very useful; for instance, the slope of the streamline at shock polar points in the hodograph plane can be obtained from them (the Busemann "hedgehog"). A particularly simple derivation was indicated by Sternberg[4], using natural coordinates. It is found that the flow variable gradients are proportional to the shock wave curvature. Tables of coefficients for streamline curvature have been computed by Thomas[2] for a limited range of Mach number.

The same gradients can be computed for axisymmetric flow. However, they are now linear combinations of the two shock curvatures, K_s in the meridianal plane and $1/r$ in the azimuthal plane. (The two-dimensional result in obtained simply by neglecting the $1/r$ term.) Because of this the general usefulness of these gradient functions is restricted in that one can no longer, as in two-dimensional flow, obtain certain quantities (e.g., slope of sonic line) without having to specify the values of r and K_s. Expressions for the slope of these contours (density, pressure, Mach number) have been given by Wood and Gooderum[5].

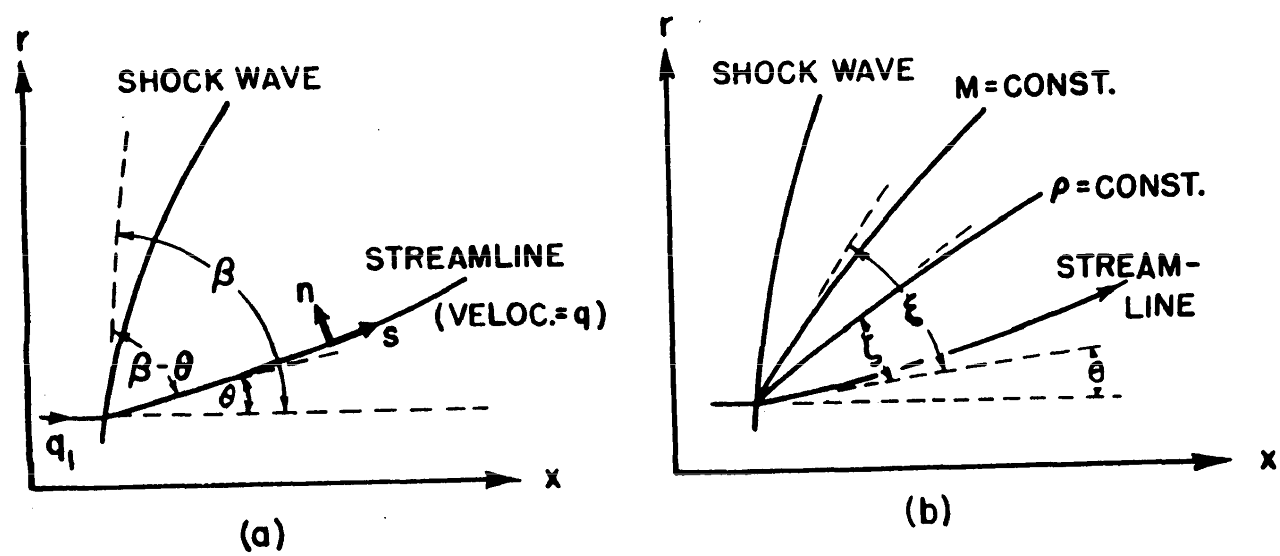

FIGURE 1.1

Aside from the results of Thomas cited above no calculations of the above-mentioned gradient quantities have to the authors' knowledge been published. This report supplies such a set of calculations ("shock gradient functions") which can be used to determine significant flow information from physical measurements. It is felt that these computations can also be helpful in obtaining a clearer general picture of flow behind a curved shock wave. These functions will find further application in the study of flow of a relaxing gas behind shock waves at large Mach numbers.

The particular quantities to be obtained here are (using the notation of Fig. 1.1): 1) $\partial q/\partial s$, the velocity gradient along the streamline; 2) $\partial \Theta/\partial s$ ($= K_\psi$), the curvature of the streamline; 3) $\Theta + \zeta$, the slope angle of the isopycnal, or density contour; and 4) $\Theta + \xi$, the slope angle of the Mach number contour. It is assumed that the gas is ideal, and that the flow is non-viscous and isentropic along streamlines.

The above flow quantities are obtainable from expressions having the following simplified forms:

$$
\begin{aligned}
\partial\Theta/\partial s &= F_1(\gamma, M_1, \beta)\, K_s + \epsilon\, F_2(\gamma, M_1, \beta)\, (1/r) \\
(1/q_1)\partial q/\partial s &= F_3(\gamma, M_1, \beta)\, K_s + \epsilon\, F_4(\gamma, M_1, \beta)\, (1/r) \\
\tan \zeta &= \frac{F_3(\gamma, M_1, \beta)\, K_s + \epsilon\, F_4(\gamma, M_1, \beta)\, (1/r)}{F_5(\gamma, M_1, \beta)\, K_s + \epsilon\, F_6(\gamma, M_1, \beta)\, (1/r)} \\
\tan \xi &= \frac{F_3(\gamma, M_1, \beta)\, K_s + \epsilon\, F_4(\gamma, M_1, \beta)\, (1/r)}{F_7(\gamma, M_1, \beta)\, K_s + \epsilon\, F_6(\gamma, M_1, \beta)\, (1/r)}
\end{aligned}
\qquad (1.1)
$$

where ϵ is equal to zero for two-dimensional flow and one for axisymmetric flow. M_1 and q_1 are the Mach number and velocity, respectively, in the free stream; $\tan \beta$ is the slope of the shock wave; γ is the ratio of specific heats. The angle $\Theta = \Theta\,(M_1, \beta)$ is known from the shock wave relations (see, e.g., Ref. 6).

The gradient functions F_1, F_2, ..., F_7 are derived in detail in Section II. These functions for the most part are long and complicated expressions in M_1 and β which do not lend themselves to analytical treatment or easy hand computation. It is, however, feasible to calculate them on a high speed computing machine. Thus the functions F_1, F_2, ..., F_7, Θ, and M have been programmed for computation by the EDVAC in the Ballistic Research Laboratories, and they can be obtained quickly for any particular case of supersonic flow by specifying M_1 and γ in the computing machine input.

The simple form of the expressions in Eqs. (1.1) suggests the practicability of a compilation of the coefficients of K_s and 1/r which could be employed as a labor saving means of determining the desired quantities. To this end, the present paper provides a series of tables of shock wave gradient functions versus β for $\gamma = 1.4$, with M_1 as parameter.

The angle ζ is of special interest to the authors, particularly in calculating a flow field (velocity, streamlines, etc.) from given interferometric density data (see Ref. 5, 7, and 8). The information resulting from the measured β and K_s reduces the uncertainty in density near a shock wave which is inherent in the interferometric method.

Sample hand computations have verified that the formulas used in this report yield the same values as formulas given in the references.

II. DERIVATION OF GRADIENT FUNCTIONS

The present derivation follows the one indicated in Ref. 4. In natural coordinates the equations of isoenergetic flow of an ideal non-viscous gas are

$$(1/\rho)\ \partial\rho/\partial s + (1/q)\ \partial q/\partial s + \partial\theta/\partial n + \epsilon(\sin\theta)/r = 0 \qquad (a)$$

$$\partial p/\partial s + \rho q\ \partial q/\partial s = 0 \qquad (b)$$

$$\partial p/\partial n + \rho\ q^2\ \partial\theta/\partial s = 0 \qquad (c) \qquad (2.1)$$

$$h + q^2/2 = \text{constant} \qquad (d)$$

$$TdS = dh - dp/\rho \qquad (e)$$

where $\epsilon = 0$ for two-dimensional, $= 1$ for axisymmetric flow. The coordinates s and n are arc lengths along the streamline and along the orthogonal trajectory of the streamline, respectively; q is the speed of flow, and θ is the angle between the streamline and the free stream direction (x axis); ρ is the density, and p the pressure. T is the temperature; M is the Mach number ($= q/a$, where $a = (\partial p/\partial\rho)^{1/2}$ = speed of sound).

The two essential equations to be used here are

$$(1 - M^2)\ (1/q)\ \partial q/\partial s + \partial\theta/\partial n = -\ \epsilon(\sin\theta)/r \qquad (a)$$

$$\partial q/\partial n - q\ \partial\theta/\partial s = -\ (T/q)\ dS/dn, \qquad (b) \qquad (2.2)$$

obtained from Eqs. (2.1) and the definition of the velocity of sound. (The foregoing equations are given in Ref. 9 and 10.) Entropy remains constant along streamlines.

If σ is arc length along the shock wave, it is seen from the relation

$$\partial/\partial\sigma = (\partial/\partial s)\ (\partial s/\partial\sigma) + (\partial/\partial n)\ (\partial n/\partial\sigma)$$

that at the shock wave

$$\frac{\partial}{\partial\sigma} = \left(\frac{\partial}{\partial\beta}\right)\left(\frac{\partial\beta}{\partial\sigma}\right) = K_s\frac{\partial}{\partial\beta} = \left(\frac{\partial}{\partial s}\right)\cos(\beta - \theta) + \left(\frac{\partial}{\partial n}\right)\sin(\beta - \theta) \qquad (2.3)$$

where tan β and K_s are the slope and curvature, respectively, of the shock wave (Fig. 1.1). As the coordinates are defined, curvatures are positive where curves are concave upward and negative where concave downward.

By means of Eq. (2.3), Eqs. (2.2) are replaced by two simultaneous linear algebraic equations for $\partial q/\partial s$ and $\partial \Theta/\partial s$. The coefficients of these equations are now converted into the desired form; namely, that of Eqs. (1.1). For this purpose use is made of the following definitions and relations which can be found in many textbooks and reference books (the authors employed Ref. 6 mainly):

$$m = M_1 \sin \beta \tag{2.4}$$

The subscript 1 always refers to free stream conditions.

$$g = \rho_1/\rho = \left[(\gamma - 1)\, m^2 + 2\right] \Big/ \left[(\gamma + 1)\, m^2\right] \tag{2.5}$$

$$\ell = p_1/p = (\gamma + 1) \Big/ \left[2\gamma m^2 - (\gamma - 1)\right] \tag{2.6}$$

$$q = A\, q_1, \tag{2.7}$$

where

$$A = (\cos^2 \beta + g^2 \sin^2 \beta)^{1/2} \tag{2.8}$$

$$\sin(\beta - \Theta) = (g \sin \beta)/A, \quad \cos(\beta - \Theta) = (\cos \beta)/A \tag{2.9}$$

$$\sin \Theta = \left[(1 - g) \sin \beta \cos \beta\right] /A \tag{2.10}$$

$$T/T_1 = g/\ell \tag{2.11}$$

$$M/M_1 = A(\ell/g)^{1/2} \tag{2.12}$$

$$S = \left(\frac{q_1}{T_1}\right) \left[\frac{q_1}{\gamma(\gamma - 1)M_1^{\,2}}\right] \left[\log_e \left(\frac{1}{\ell}\right) - \gamma \log_e \left(\frac{1}{g}\right)\right] + S_1 \tag{2.13}$$

After differentiation for $\partial q/\partial \beta$, $\partial \Theta/\partial \beta$, and $\partial S/\partial \beta$ (noting that $\partial S/\partial s = 0$), one obtains expression for F_1, F_2, F_3, and F_4 given by the following sequence of formulas:

$$L(m) = g^2 - 1 - 4g/(\gamma m^2 + m^2) \qquad (2.14)$$

$$K(m) = (1 - m^2 g \ell)^{-1} \qquad (2.15)$$

$$J(m) = \frac{-\left[g/(\gamma + 1)\right]\left[4m^2\ell - 2(\gamma + 1) + 2(\gamma - 1)/g\right]}{(\gamma - 1)\,\ell\, m^2\, L(m)} \qquad (2.16)$$

$$f_1 = g\left[L(1 - J) - K(1 - g)\right] \qquad (2.17)$$

$$f_2 = -K\left[(L - g + 1)/g + m^2\,\ell\, L\,(1 - J)\right] \qquad (2.18)$$

$$f_3 = g\,K(1 - g) \qquad (2.19)$$

$$f_4 = K\left[(L - g + 1) + L(1 - J)\right] \qquad (2.20)$$

$$F_1 = \left[(\cos\beta)/A^3\right]\left(f_1 \sin^2\beta + f_2\cos^2\beta\right) \qquad (2.21)$$

$$F_2 = \left[(\cos\beta)/A^3\right]\left(f_3 \sin^2\beta\cos\beta\right) \qquad (2.22)$$

$$F_3 = \left[(\sin\beta)/A^2\right]\left(f_4\cos^2\beta + g\, f_3 \sin^2\beta\right) \qquad (2.23)$$

$$F_4 = -\left(g\, f_3 \sin^3\beta\cos\beta\right)/A^2 \qquad (2.24)$$

$$\partial\theta/\partial s = F_1\, K_s + \epsilon\, F_2\,(1/r)$$

$$(1/q_1)\,\partial q/\partial s = F_3\, K_s + \epsilon\, F_4\,(1/r)$$

The following relations, obtained from the flow equations, are used to find ζ and ξ:

$$p = \left(\frac{p_t}{\rho_t{}^{\gamma}}\right)\rho^{\gamma} = \left[\frac{(p_t/p_{t_1})}{(\rho_t/\rho_{t_1})^{\gamma}}\ \frac{(\rho_1/\rho_{t_1})^{\gamma}}{(p_1/p_{t_1})}\ \frac{p_1}{\rho_1{}^{\gamma}}\right]\rho^{\gamma} \qquad (2.25)$$

where the subscript t denotes the stagnation value ($\partial p_t/\partial s = \partial\rho_t/\partial s = 0$), and

$$p_t/p_{t_1} = \rho_t/\rho_{t_1} = R = \ell^{\,1/(\gamma - 1)}\ g^{-\gamma/(\gamma - 1)} \qquad \text{(See Ref. 6)}$$

$$\rho_1/\rho_{t_1} = \left[1 + (\gamma - 1) M_1^2/2\right]^{-1/(\gamma - 1)}$$

$$p_1/p_{t_1} = \left[1 + (\gamma - 1) M_1^2/2\right]^{-\gamma/(\gamma - 1)}$$

By means of Eqs. (2.3) and (2.25), $\partial p/\partial s$ and $\partial p/\partial n$ can be expressed in terms of $\partial \rho/\partial s$, $\partial \rho/\partial n$, and other quantities already determined in this report. Substituting these expressions into Eqs.(2.1), one then derives expressions for $\partial \rho/\partial s$ and $\partial \rho/\partial n$; and putting these into the relation for the angle between the density contour and the streamline, namely,

$$\tan \zeta = - (\partial \rho/\partial s)/(\partial \rho/\partial n) \qquad (2.26)$$

one obtains

$$\tan \zeta = \frac{F_3 K_s + \epsilon F_4 (1/r)}{F_5 K_s + \epsilon F_6 (1/r)}, \text{ where}$$

$$F_5 = \frac{4 \cos \beta}{\gamma + 1} \left[\frac{1}{g\ell m^4} - 1\right] - AF_1 \qquad (2.27)$$

$$F_6 = - AF_2 \qquad (2.28)$$

A positive value of ζ indicates a counterclockwise rotation from the streamline to the density contour.

The angle ξ between the Mach number contour and the streamline is determined from

$$\tan \xi = - (\partial M/\partial s)/(\partial M/\partial n) = - (\partial M^2/\partial s)/(\partial M^2/\partial n), \qquad (2.29)$$

where ξ has the same sign convention as ζ. Since

$$M^2 = (\rho q^2)/(\gamma p),$$

$\partial M^2 \partial s$ and $\partial M^2/\partial n$ can be expressed in terms of the derivatives of ρ and q, which in turn are expressible in terms of previously determined quantities.

Consequently one obtains

$$\tan \xi = \frac{F_3 K_s + \epsilon F_4 (1/r)}{F_7 K_s + \epsilon F_6 (1/r)} \quad \text{, where}$$

$$F_7 = - \left[\frac{4 \cos \beta}{(\gamma + 1) g^2 m^2 \sin^2 \beta} \left\{ A^2 - \frac{2g (m^2 - 1)^2 \sin^2 \beta}{(\gamma + 1) m^2} \right\} + \left\{ \frac{(A^3 \gamma \ell m^2/g) + 2 A \sin^2 \beta}{\sin^2 \beta} \right\} F_1 + \left\{ \frac{A^2 m^2 \ell \cot \beta}{g^2 \sin^2 \beta} \right\} F_3 \right] \cdot \left[2 + (\gamma - 1) \frac{A^2 m^2 \ell}{g \sin^2 \beta} \right]^{-1} \tag{2.30}$$

III. DISCUSSION OF COMPUTATIONS

Tabulations of the functions F_1, F_2, ..., F_7, Θ, and M, calculated for $\gamma = 1.4$, are presented in Section 4 for values of M_1 ranging from 1.1 to 10.0. The functions are listed in order of decreasing β, from $\beta = 90^\circ$ to a value somewhat greater than $\beta = \sin^{-1}(1/M_1)$. The listed values of M_1 and β were chosen so as to permit the determination of the functions to a reasonable degree of accuracy for any M_1 and β by means of graphical interpolation.

Figure 3.1 shows an example of results obtainable from these calculations. The right hand curve shows the variation in slope of the constant density lines along the shock wave of a supersonic sphere in nitrogen (shown at the left) determined from shock wave coordinate measurements and the appropriate shock gradient functions. For reference purposes, the left hand figure shows the sonic point and "Crocco point" (defined below), and indicates the location of typical values of rK_s. It must be noted that the accuracy of results like those in Figure 3.1 is restricted by the limited accuracy of β and K_s

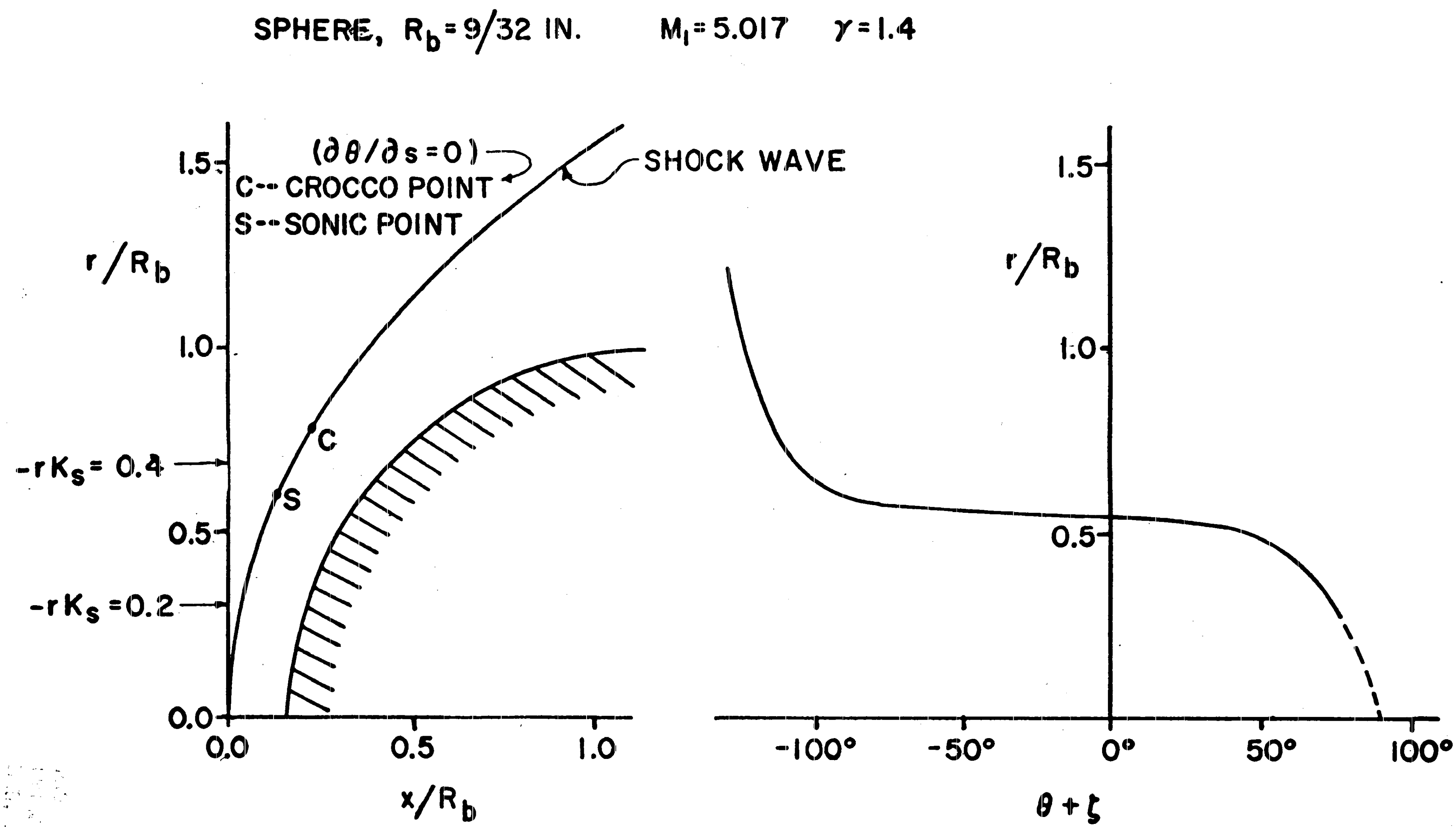

Figure 3.1. EXAMPLE OF VARIATON OF ANGLE OF CONSTANT DENSITY LINES ALONG A DETACHED SHOCK WAVE.

determined from experiment. (See Ref. 5 and 8 for discussion on determination of β and K_s.)

A point often referred to in two-dimensional flow studies (e.g., Ref. 3) is the "Crocco point", where the streamline curvature is zero. Figure 3.2 shows the geometrical conditions which must exist at the Crocco point in plane and axisymmetric flows for $\gamma = 1.4$. It can be seen that in two-dimensional flow the Crocco point always lies below the sonic point on a shock wave of continuosuly decreasing slope. The two points approach coincidence with increasing Mach number. On the other hand, in axisymmetric flow the sonic point lies below the Crocco point for all values of M_1 and rK_s shown. By continuity there would be values of these two parameters for which the sonic point lies above the Crocco point.

The slope of the sonic line is a quantity of considerable interest. It can be otained from the tables by evaluating the β and shock gradient functions corresponding to $M = 1$ (e.g., by graphical interpolation); it is found to be given by

$$\tan\,(\theta + \xi)_{son.} = \frac{B_1\,(M_1)\,rK_s + 1}{B_2\,(M_1)\,rK_s + B_3(M_1)},$$

where B_1, B_2, and B_3 are given in Table 3.1 for $\gamma = 1.4$. It is seen that, formally, $rK_s = -\infty$ corresponds to two-dimensional flow. This particular case is plotted, in slightly different form, in Ref. 11.

Figure 3.3 shows plots of the variation of $\xi_{son.}$, the angle between the streamline and Mach number contour at the sonic point. For two-dimensional flow ξ is negative, indicating that the sonic line has a smaller slope than the streamline. For axisymmetric flow the figure indicates that the sonic line can have a greater slope than the streamline. (The streamline curvature must be positive in this case. This can be seen from Eqs. (2.1b) and (2.1c) and the fact that $dq/d\sigma < 0$ and $dM/d\sigma > 0$ along a shock wave with continuously decreasing slope.) If $rK_s = -.2$ at the sonic point, the sonic line and streamline are nearly tangent to each other over a very wide range of Mach number.

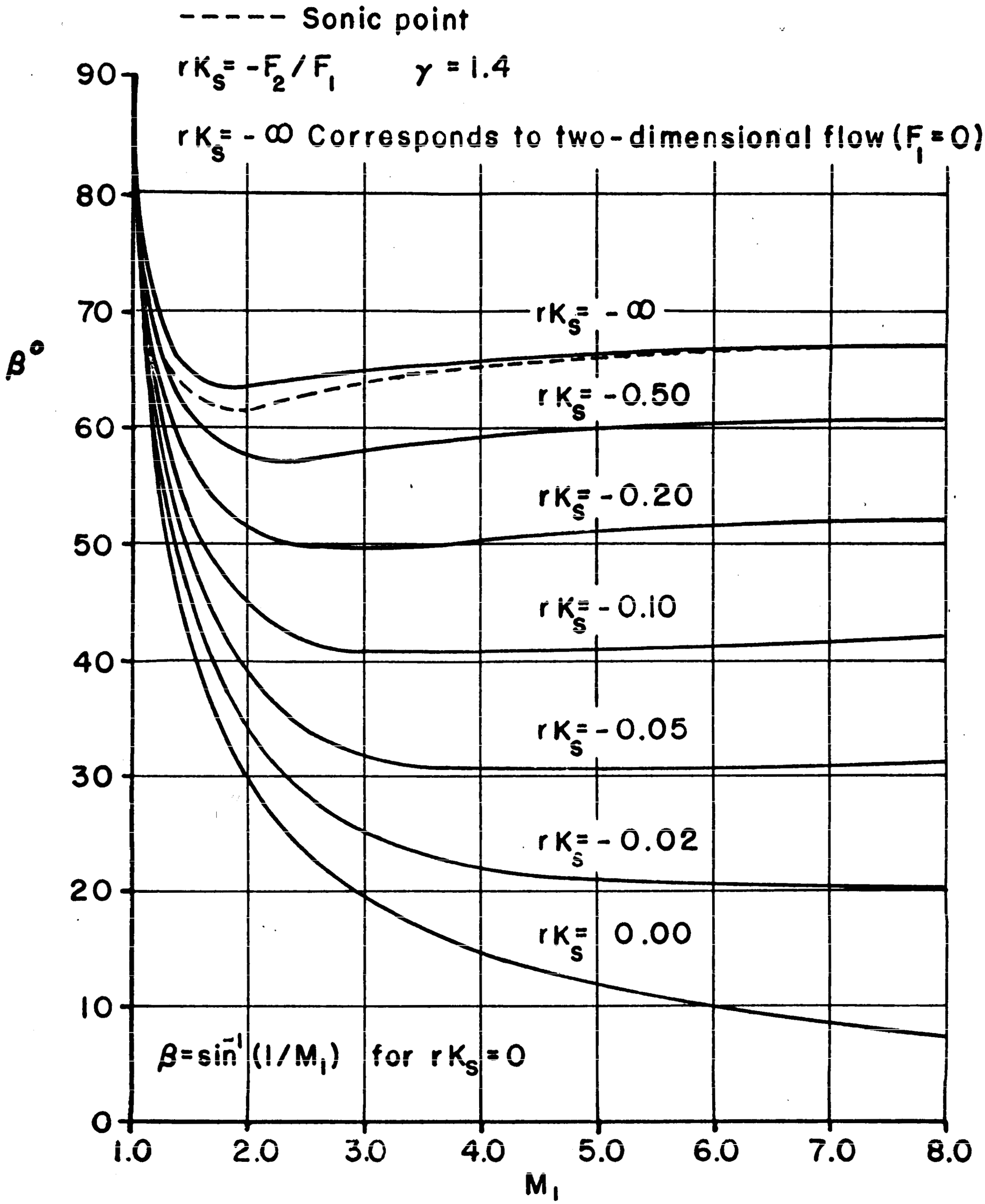

Figure 3.2. Conditions for zero curvature of streamline ($\partial\theta/\partial s = 0$) at shock wave (Crocco Point).

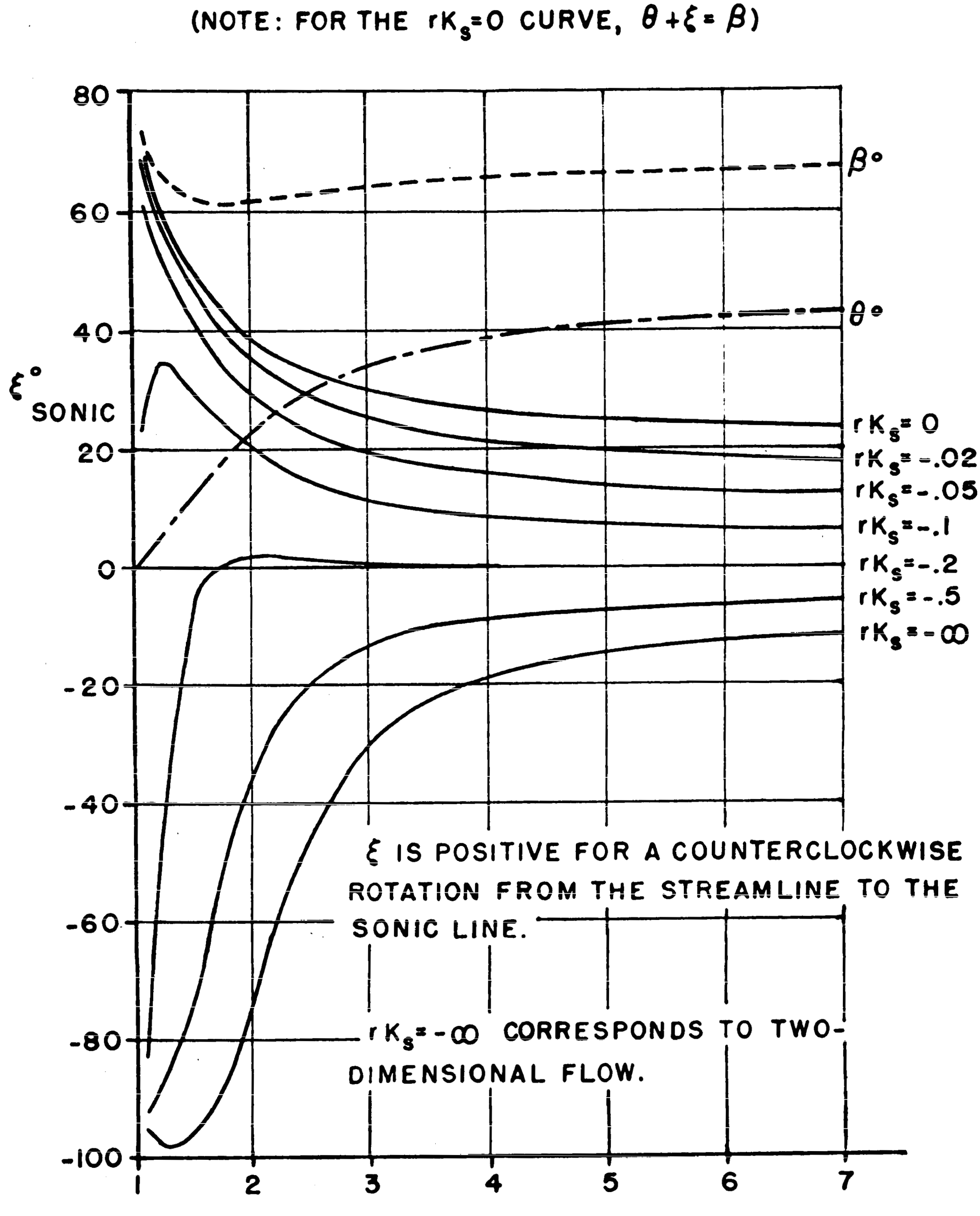

FIGURE 3.3. VARIATION OF ANGLE BETWEEN STREAMLINE AND SONIC LINE AT SHOCK WAVE.

The values of M are also useful in finding the slopes of the characteristics at the shock wave in the supersonic portion of the flow field.

For quick reference, Eqs. (1.1) are restated here.

$$\partial\theta/\partial s = F_1 K_s + F_2 (1/r)$$

$$(1/q_1)(\partial q/\partial s) = F_3 K_s + F_4 (1/r)$$

$$\tan \zeta = \frac{F_3(rK_s) + F_4}{F_5(rK_s) + F_6}$$

$$\tan \xi = \frac{F_3(rK_s) + F_4}{F_7(rK_s) + F_6}$$

TABLE 3.1

Sonic Point Table ($\gamma = 1.4$)

M_1	B_1	B_2	B_3	β°	θ°
1.10	10.03	.793	.301	73.26	1.40
1.30	6.15	.175	.464	65.11	6.31
1.50	4.78	- 0.548	.524	62.26	11.71
1.75	3.71	- 1.40	.546	61.31	17.77
2.00	2.76	- 2.29	.541	61.50	22.70
2.50	1.16	- 3.91	.517	62.66	29.65
3.00	- 0.31	- 5.23	.492	63.77	33.99
3.50	- 1.53	- 6.27	.474	64.62	36.82
4.00	- 2.56	- 7.09	.458	65.26	38.74
4.50	- 3.38	- 7.70	.451	65.73	40.06
5.00	- 4.04	- 8.20	.444	66.08	41.03
6.00	- 5.04	- 8.92	.435	66.58	42.32
7.00	- 5.70	- 9.38	.428	66.88	43.16
8.00	- 6.19	- 9.72	.424	67.09	43.64
9.00	- 6.50	- 9.92	.420	67.22	44.03
10.00	- 6.76	-10.09	.419	67.35	44.27

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IV - TABLES OF SHOCK GRADIENT FUNCTIONS

$M_1 = 1.10$ $\gamma = 1.4$

β^o	θ^o	F_1	$10F_2$	F_3	F_4	F_5	$10F_6$	F_7	M
90	0.000	0.0000	.00000	0.8574	.00000	0.0000	.00000	0.0000	0.912
89	0.169	-0.0543	.00357	0.8502	-.01495	0.0463	-.00305	0.0469	0.912
88	0.336	-0.1074	.01421	0.8283	-.02985	0.0916	-.01217	0.0928	0.913
87	0.498	-0.1581	.03181	0.7917	-.04463	0.1351	-.02728	0.1369	0.915
86	0.655	-0.2054	.05612	0.7399	-.05923	0.1759	-.04823	0.1781	0.917
85	0.804	-0.2479	.08683	0.6724	-.07361	0.2128	-.07482	0.2156	0.920
84	0.944	-0.2844	.12354	0.5885	-.08770	0.2450	-.10681	0.2482	0.923
83	1.072	-0.3136	.16580	0.4871	-.10147	0.2712	-.14390	0.2747	0.927
82	1.187	-0.3341	.21309	0.3668	-.11485	0.2902	-.18575	0.2940	0.932
81	1.287	-0.3444	.26484	0.2258	-.12782	0.3005	-.23200	0.3046	0.938
80	1.371	-0.3427	.32045	0.0616	-.14034	0.3006	-.28224	0.3048	0.944
78	1.483	-0.2941	.44071	-0.3513	-.16390	0.2611	-.39298	0.2653	0.957
76	1.514	-0.1645	.56876	-0.9167	-.18532	0.1476	-.51442	0.1515	0.974
74	1.454	0.0901	.69956	-1.7246	-.20447	-0.0838	-.64288	-0.0805	0.992
72	1.295	0.5642	.82849	-2.9781	-.22131	-0.5283	-.77479	-0.5259	1.013
70	1.032	1.5152	.95145	-5.2381	-.23582	-1.4444	-.90674	-1.4430	1.037

$M_1 = 1.30$ $\gamma = 1.4$

β^o	θ^o	F_1	F_2	F_3	F_4	F_5	F_6	F_7	M
90	0.000	0.0000	.00000	0.8900	.00000	0.0000	.00000	0.0000	0.786
89	0.515	-0.0796	.00062	0.8856	-.01552	0.0513	-.00041	0.0556	0.786
88	1.027	-0.1578	.00248	0.8725	-.03095	0.1019	-.00164	0.1104	0.787
87	1.532	-0.2335	.00553	0.8506	-.04621	0.1510	-.00366	0.1637	0.789
86	2.028	-0.3054	.00973	0.8202	-.06122	0.1981	-.00647	0.2149	0.792
85	2.511	-0.3724	.01501	0.7814	-.07590	0.2423	-.01001	0.2632	0.795
84	2.979	-0.4334	.02127	0.7344	-.09018	0.2832	-.01425	0.3079	0.799
83	3.427	-0.4873	.02842	0.6794	-.10399	0.3201	-.01914	0.3484	0.804
82	3.855	-0.5335	.03634	0.6168	-.11727	0.3523	-.02462	0.3841	0.810
81	4.260	-0.5711	.04491	0.5466	-.12998	0.3795	-.03063	0.4146	0.816
80	4.638	-0.5996	.05400	0.4693	-.14208	0.4011	-.03711	0.4391	0.823
78	5.309	-0.6269	.07327	0.2938	-.16429	0.4257	-.05120	0.4689	0.839
76	5.856	-0.6125	.09317	0.0916	-.18376	0.4228	-.06636	0.4699	0.857
74	6.267	-0.5544	.11282	-0.1370	-.20043	0.3891	-.08207	0.4386	0.878
72	6.535	-0.4507	.13148	-0.3935	-.21436	0.3210	-.09785	0.3715	0.902
70	6.655	-0.2991	.14860	-0.6813	-.22569	0.2138	-.11329	0.2637	0.928
65	6.299	0.3298	.18228	-1.5998	-.24390	-0.2803	-.14829	-0.2384	1.002
60	5.013	1.5662	.20143	-3.1378	-.25056	-1.3724	-.17553	-1.3461	1.089
55	2.836	5.0595	.20685	-7.3220	-.24903	-4.7334	-.19342	-4.7248	1.191

$M_1 = 1.50$ $\gamma = 1.4$

β^o	θ^o	F_1	F_2	F_3	F_4	F_5	F_6	F_7	M
90	00.00	0.0000	.00000	0.9105	.00000	0.0000	.00000	0.0000	0.701
89	00.86	-0.1089	.00096	0.9062	-.01587	0.0557	-.00052	0.0655	0.702
88	01.72	-0.2159	.00382	0.8933	-.03162	0.1106	-.00205	0.1301	0.703
87	02.56	-0.3189	.00850	0.8720	-.04713	0.1638	-.00459	0.1929	0.705
86	03.39	-0.4162	.01491	0.8425	-.06229	0.2146	-.00808	0.2531	0.708
85	04.20	-0.5061	.02290	0.8052	-.07699	0.2621	-.01248	0.3099	0.712
84	04.99	-0.5872	.03229	0.7604	-.09114	0.3056	-.01770	0.3626	0.717
83	05.75	-0.6583	.04289	0.7088	-.10466	0.3447	-.02368	0.4105	0.723
82	06.48	-0.7184	.05448	0.6507	-.11748	0.3787	-.03033	0.4530	0.729
81	07.17	-0.7669	.06685	0.5868	-.12955	0.4073	-.03756	0.4898	0.737
80	07.82	-0.8032	.07977	0.5176	-.14082	0.4300	-.04527	0.5203	0.745
78	09.00	-0.8389	.10644	0.3654	-.16089	0.4569	-.06176	0.5615	0.764
76	10.00	-0.8262	.13293	0.1982	-.17762	0.4580	-.07907	0.5751	0.785
74	10.81	-0.7678	.15799	0.0196	-.19111	0.4329	-.09656	0.5601	0.810
72	11.42	-0.6680	.18070	-0.1682	-.20156	0.3816	-.11367	0.5166	0.837
70	11.84	-0.5309	.20047	-0.3636	-.20929	0.3042	-.12997	0.4442	0.866
65	12.06	-0.0472	.23560	-0.8890	-.21883	-0.0069	-.16523	0.1332	0.949
60	11.16	0.6374	.25133	-1.5074	-.21844	-0.5192	-.19094	-0.3970	1.045
55	09.26	1.6434	.25151	-2.3673	-.21215	-1.3759	-.20672	-1.2875	1.152
50	06.44	3.5288	.24037	-3.9945	-.20270	-3.1431	-.21319	-3.0970	1.271

$M_1 = 1.75$ $\gamma = 1.4$

β^o	θ^o	F_1	F_2	F_3	F_4	F_5	F_6	F_7	M
90	00.00	0.0000	.00000	0.9269	.00000	0.0000	.00000	0.0000	0.628
89	01.28	-0.1497	.00146	0.9221	-.01615	0.0607	-.00064	0.0783	0.629
88	02.55	-0.2961	.00580	0.9078	-.03212	0.1204	-.00255	0.1554	0.630
87	03.80	-0.4359	.01288	0.8843	-.04776	0.1777	-.00569	0.2301	0.633
86	05.03	-0.5660	.02248	0.8520	-.06289	0.2318	-.00999	0.3013	0.637
85	06.22	-0.6841	.03430	0.8115	-.07740	0.2816	-.01536	0.3681	0.642
84	07.38	-0.7880	.04801	0.7636	-.09114	0.3264	-.02168	0.4296	0.648
83	08.50	-0.8761	.06323	0.7089	-.10403	0.3655	-.02884	0.4850	0.655
82	09.56	-0.9475	.07957	0.6483	-.11600	0.3984	-.03671	0.5339	0.663
81	10.57	-1.0016	.09663	0.5827	-.12699	0.4247	-.04514	0.5757	0.672
80	11.52	-1.0385	.11406	0.5130	-.13697	0.4442	-.05400	0.6103	0.682
78	13.23	-1.0623	.14869	0.3642	-.15390	0.4626	-.07252	0.6570	0.705
76	14.68	-1.0255	.18122	0.2077	-.16693	0.4539	-.09134	0.6741	0.731
74	15.87	-0.9375	.21012	0.0482	-.17639	0.4200	-.10968	0.6629	0.760
72	16.80	-0.8087	.23455	-0.1110	-.18273	0.3629	-.12700	0.6253	0.792
70	17.47	-0.6484	.25418	-0.2681	-.18642	0.2851	-.14290	0.5632	0.826
65	18.12	-0.1583	.28343	-0.6476	-.18713	0.0123	-.17524	0.3118	0.922
60	17.48	0.4126	.28988	-1.0210	-.18036	-0.3636	-.19666	-0.0709	1.029
55	15.75	1.0718	.28116	-1.4300	-.17018	-0.8673	-.20826	-0.6105	1.147
50	13.08	1.9253	.26322	-1.9676	-.15898	-1.6036	-.21162	-1.4085	1.276
45	09.59	3.3278	.23991	-2.8902	-.14797	-2.9203	-.20814	-2.8039	1.415
40	05.30	7.0134	.21332	-5.4093	-.13764	-6.5463	-.19877	-6.5066	1.569

$M_1 = 2.00$ $\gamma = 1.4$

β^o	θ^o	F_1	F_2	F_3	F_4	F_5	F_6	F_7	M
90	00.00	0.0000	.00000	0.9375	.00000	0.0000	.00000	0.0000	0.577
89	01.66	-0.1930	.00202	0.9320	-.01632	0.0652	-.00076	0.0906	0.578
88	03.32	-0.3807	.00801	0.9158	-.03241	0.1289	-.00302	0.1797	0.580
87	04.94	-0.5579	.01771	0.8891	-.04806	0.1896	-.00671	0.2656	0.583
86	06.53	-0.7204	.03073	0.8528	-.06304	0.2459	-.01172	0.3471	0.588
85	08.08	-0.8643	.04657	0.8076	-.07721	0.2969	-.01794	0.4228	0.594
84	09.57	-0.9869	.06465	0.7546	-.09040	0.3415	-.02518	0.4919	0.601
83	10.99	-1.0866	.08436	0.6950	-.10253	0.3789	-.03329	0.5534	0.610
82	12.34	-1.1626	.10509	0.6300	-.11351	0.4089	-.04208	0.6070	0.619
81	13.61	-1.2149	.12627	0.5606	-.12332	0.4310	-.05137	0.6523	0.630
80	14.81	-1.2443	.14736	0.4880	-.13195	0.4453	-.06099	0.6891	0.642
78	16.94	-1.2406	.18759	0.3373	-.14577	0.4511	-.08060	0.7380	0.669
76	18.73	-1.1664	.22317	0.1847	-.15538	0.4285	-.09986	0.7555	0.699
74	20.18	-1.0387	.25268	0.0350	-.16136	0.3811	-.11799	0.7448	0.733
72	21.30	-0.8735	.27570	-0.1085	-.16435	0.3130	-.13451	0.7092	0.769
70	22.12	-0.6842	.29246	-0.2445	-.16498	0.2277	-.14915	0.6521	0.808
65	22.97	-0.1643	.31134	-0.5506	-.15966	-0.0417	-.17714	0.4314	0.917
60	22.41	0.3686	.30713	-0.8205	-.14919	-0.3714	-.19380	0.1147	1.037
55	20.73	0.9094	.28996	-1.0815	-.13714	-0.7626	-.20125	-0.3025	1.167
50	18.13	1.5083	.26635	-1.3758	-.12534	-1.2544	-.20160	-0.8597	1.307
45	14.74	2.2937	.23999	-1.7828	-.11460	-1.9619	-.19646	-1.6672	1.456
40	10.62	3.6349	.21267	-2.5176	-.10524	-3.2449	-.18695	-3.0717	1.617
35	05.75	7.3335	.18491	-4.6213	-.09724	-6.9018	-.17361	-6.8444	1.795

$M_1 = 2.50$ $\gamma = 1.4$

β^o	θ^o	F_1	F_2	F_3	F_4	F_5	F_6	F_7	M
90	00.00	0.0000	.00000	0.9500	.00000	0.0000	.00000	0.0000	0.513
89	02.33	-0.2793	.00320	0.9430	-.01652	0.0725	-.00096	0.1124	0.514
88	04.64	-0.5479	.01259	0.9224	-.03269	0.1427	-.00380	0.2224	0.517
87	06.90	-0.7958	.02761	0.8889	-.04818	0.2082	-.00841	0.3276	0.521
86	09.09	-1.0149	.04736	0.8439	-.06271	0.2671	-.01458	0.4260	0.527
85	11.21	-1.1994	.07077	0.7889	-.07604	0.3180	-.02210	0.5160	0.535
84	13.22	-1.3456	.09666	0.7258	-.08803	0.3596	-.03069	0.5964	0.545
83	15.12	-1.4524	.12385	0.6564	-.09858	0.3914	-.04008	0.6666	0.556
82	16.91	-1.5209	.15129	0.5827	-.10765	0.4131	-.04999	0.7262	0.568
81	18.57	-1.5534	.17807	0.5062	-.11527	0.4249	-.06019	0.7753	0.582
80	20.10	-1.5536	.20345	0.4286	-.12150	0.4273	-.07044	0.8143	0.597
78	22.78	-1.4741	.24811	0.2746	-.13019	0.4064	-.09042	0.8644	0.631
76	24.96	-1.3170	.28300	0.1280	-.13462	0.3565	-.10887	0.8821	0.669
74	26.68	-1.1134	.30792	-0.0073	-.13578	0.2844	-.12520	0.8735	0.711
72	27.97	-0.8867	.32382	-0.1295	-.13453	0.1959	-.13917	0.8440	0.756
70	28.89	-0.6533	.33216	-0.2387	-.13161	0.0961	-.15079	0.7979	0.804
65	29.80	-0.0961	.32971	-0.4619	-.12031	-0.1816	-.17053	0.6281	0.934
60	29.18	0.3904	.30845	-0.6328	-.10714	-0.4768	-.17958	0.3966	1.077
55	27.44	0.8175	.27971	-0.7748	-.09443	-0.7818	-.18097	0.1034	1.231
50	24.85	1.2221	.24923	-0.9102	-.08307	-1.1076	-.17697	-0.2682	1.395
45	21.57	1.6594	.21961	-1.0648	-.07334	-1.4884	-.16924	-0.7548	1.569
40	17.68	2.2266	.19189	-1.2814	-.06525	-2.0071	-.15891	-1.4357	1.754
35	13.17	3.1621	.16625	-1.6642	-.05875	-2.8952	-.14670	-2.5278	1.952
30	07.99	5.4086	.14226	-2.6251	-.05370	-5.0966	-.13288	-4.9407	2.169

$M_1 = 3.00$ $\gamma = 1.4$

β°	θ°	F_1	F_2	F_3	F_4	F_5	F_6	F_7	M
90	00.00	0.0000	.00000	0.9568	.00000	0.0000	.00000	0.0000	0.475
89	02.85	-0.3576	.00431	0.9484	-.01662	0.0782	-.00112	0.1298	0.476
88	05.67	-0.6978	.01687	0.9237	-.03277	0.1530	-.00441	0.2563	0.480
87	08.42	-1.0051	.03669	0.8840	-.04804	0.2215	-.00970	0.3763	0.485
86	11.07	-1.2674	.06229	0.8312	-.06207	0.2812	-.01671	0.4872	0.493
85	13.60	-1.4771	.09189	0.7678	-.07461	0.3302	-.02511	0.5872	0.502
84	15.99	-1.6312	.12368	0.6963	-.08550	0.3675	-.03453	0.6751	0.514
83	18.22	-1.7304	.15598	0.6193	-.09469	0.3926	-.04461	0.7504	0.527
82	20.29	-1.7787	.18737	0.5393	-.10221	0.4058	-.05502	0.8133	0.542
81	22.19	-1.7819	.21677	0.4583	-.10813	0.4078	-.06547	0.8643	0.558
80	23.93	-1.7472	.24343	0.3779	-.11259	0.3993	-.07574	0.9043	0.576
78	26.90	-1.5923	.28699	0.2240	-.11777	0.3560	-.09502	0.9554	0.616
76	29.25	-1.3659	.31716	0.0840	-.11902	0.2850	-.11197	0.9754	0.660
74	31.06	-1.1072	.33532	-0.0395	-.11751	0.1949	-.12626	0.9720	0.708
72	32.38	-0.8421	.34371	-0.1467	-.11418	0.0924	-.13789	0.9516	0.760
70	33.28	-0.5856	.34465	-0.2388	-.10971	-0.0175	-.14707	0.9183	0.814
65	34.07	-0.0209	.32680	-0.4158	-.09647	-0.3039	-.16101	0.7958	0.961
60	33.32	0.4288	.29544	-0.5393	-.08308	-0.5874	-.16532	0.6285	1.123
55	31.49	0.7935	.26084	-0.6319	-.07099	-0.8604	-.16316	0.4140	1.296
50	28.86	1.1114	.22734	-0.7104	-.06058	-1.1276	-.15668	0.1382	1.482
45	25.62	1.4234	.19659	-0.7901	-.05185	-1.4046	-.14737	-0.2227	1.681
40	21.85	1.7821	.16905	-0.8897	-.04469	-1.7277	-.13629	-0.7090	1.894
35	17.58	2.2839	.14465	-1.0436	-.03897	-2.1835	-.12419	-1.4041	2.122
30	12.77	3.1850	.12300	-1.3429	-.03458	-3.0261	-.11152	-2.5422	2.367
25	07.28	5.6371	.10337	-2.1959	-.03142	-5.4158	-.09835	-5.2321	2.638

$M_1 = 3.50$ $\gamma = 1.4$

β°	θ°	F_1	F_2	F_3	F_4	F_5	F_6	F_7	M
90	00.00	0.0000	.00000	0.9609	.00000	0.0000	.00000	0.0000	0.451
89	03.25	-0.4242	.00527	0.9513	-.01667	0.0824	-.00124	0.1434	0.452
88	06.46	-0.8240	.02056	0.9231	-.03279	0.1606	-.00488	0.2825	0.456
87	09.58	-1.1782	.04441	0.8782	-.04784	0.2310	-.01067	0.4136	0.462
86	12.57	-1.4715	.07471	0.8190	-.06142	0.2905	-.01827	0.5336	0.471
85	15.40	-1.6952	.10902	0.7489	-.07328	0.3371	-.02726	0.6405	0.482
84	18.06	-1.8477	.14498	0.6711	-.08328	0.3700	-.03718	0.7333	0.495
83	20.51	-1.9326	.18049	0.5888	-.09141	0.3890	-.04761	0.8118	0.510
82	22.77	-1.9572	.21393	0.5047	-.09774	0.3948	-.05820	0.8766	0.527
81	24.82	-1.9313	.24420	0.4210	-.10244	0.3884	-.06863	0.9286	0.545
80	26.67	-1.8647	.27061	0.3395	-.10567	0.3713	-.07868	0.9693	0.565
78	29.80	-1.6480	.31108	0.1875	-.10855	0.3109	-.09704	1.0221	0.609
76	32.22	-1.3709	.33603	0.0538	-.10789	0.2247	-.11259	1.0459	0.658
74	34.04	-1.0764	.34818	-0.0606	-.10493	0.1223	-.12521	1.0492	0.711
72	35.34	-0.7892	.35068	-0.1571	-.10057	0.0103	-.13509	1.0383	0.767
70	36.19	-0.5220	.34632	-0.2378	-.09545	-0.1062	-.14255	1.0176	0.827
65	36.85	0.0376	.31858	-0.3865	-.08170	-0.3997	-.15270	0.9361	0.987
60	35.97	0.4587	.28154	-0.4834	-.06870	-0.6797	-.15412	0.8203	1.163
55	34.05	0.7836	.24401	-0.5502	-.05737	-0.9399	-.14987	0.6651	1.353
50	31.39	1.0524	.20925	-0.6012	-.04780	-1.1821	-.14192	0.4569	1.558
45	28.16	1.3001	.17821	-0.6475	-.03986	-1.4148	-.13166	0.1751	1.779
40	24.46	1.5642	.15099	-0.7007	-.03338	-1.6572	-.12005	-0.2098	2.018
35	20.35	1.9006	.12736	-0.7778	-.02820	-1.9537	-.10784	-0.7481	2.277
30	15.78	2.4312	.10694	-0.9159	-.02420	-2.4207	-.09554	-1.5503	2.558
25	10.68	3.5499	.08920	-1.2335	-.02130	-3.4561	-.08343	-2.9817	2.864
20	04.77	7.9361	.07323	-2.5313	-.01942	-7.7610	-.07132	-7.6495	3.212

$M_1 = 4.00$ $\gamma = 1.4$

β^o	θ^o	F_1	F_2	F_3	F_4	F_5	F_6	F_7	M
90	00.00	0.0000	.00000	0.9635	.00000	0.0000	.00000	0.0000	0.435
89	03.56	-0.4790	.00607	0.9529	-.01671	0.0856	-.00133	0.1538	0.436
88	07.07	-0.9270	.02362	0.9219	-.03277	0.1664	-.00523	0.3026	0.441
87	10.46	-1.3176	.05073	0.8727	-.04763	0.2378	-.01140	0.4420	0.447
86	13.71	-1.6327	.08471	0.8086	-.06084	0.2967	-.01943	0.5687	0.457
85	16.76	-1.8634	.12254	0.7334	-.07215	0.3410	-.02880	0.6805	0.469
84	19.60	-2.0098	.16137	0.6509	-.08145	0.3699	-.03903	0.7766	0.483
83	22.22	-2.0787	.19885	0.5648	-.08877	0.3837	-.04965	0.8571	0.499
82	24.60	-2.0811	.23326	0.4780	-.09424	0.3834	-.06026	0.9231	0.518
81	26.74	-2.0295	.26353	0.3929	-.09805	0.3705	-.07057	0.9759	0.538
80	28.66	-1.9368	.28912	0.3111	-.10043	0.3467	-.08036	1.0173	0.559
78	31.87	-1.6726	.32620	0.1615	-.10180	0.2736	-.09786	1.0723	0.607
76	34.32	-1.3598	.34660	0.0332	-.09996	0.1766	-.11227	1.1001	0.659
74	36.12	-1.0421	.35404	-0.0743	-.09616	0.0655	-.12363	1.1099	0.716
72	37.39	-0.7423	.35224	-0.1631	-.09128	-0.0530	-.13226	1.1080	0.776
70	38.20	-0.4704	.34422	-0.2360	-.08588	-0.1742	-.13852	1.0981	0.839
65	38.74	0.0806	.31014	-0.3663	-.07211	-0.4736	-.14616	1.0509	1.009
60	37.76	0.4801	.26979	-0.4469	-.05960	-0.7536	-.14574	0.9764	1.196
55	35.77	0.7782	.23076	-0.4984	-.04891	-1.0091	-.14018	0.8682	1.398
50	33.07	1.0159	.19547	-0.5339	-.03998	-1.2407	-.13134	0.7126	1.619
45	29.85	1.2254	.16444	-0.5623	-.03263	-1.4530	-.12047	0.4904	1.860
40	26.20	1.4366	.13755	-0.5919	-.02665	-1.6568	-.10850	0.1759	2.123
35	22.18	1.6883	.11445	-0.6334	-.02188	-1.8778	-.09615	-0.2698	2.412
30	17.78	2.0544	.09475	-0.7066	-.01818	-2.1812	-.08396	-0.9183	2.728
25	12.94	2.7353	.07801	-0.8645	-.01545	-2.7671	-.07230	-1.9546	3.077
20	07.44	4.6432	.06361	-1.3444	-.01364	-4.5626	-.06124	-4.2388	3.466

$M_1 = 4.50$ $\gamma = 1.4$

β^o	θ^o	F_1	F_2	F_3	F_4	F_5	F_6	F_7	M
90	00.00	0.0000	.00000	0.9654	.00000	0.0000	.00000	0.0000	0.424
89	03.80	-0.5236	.00674	0.9539	-.01673	0.0881	-.00140	0.1619	0.425
88	07.54	-1.0103	.02611	0.9206	-.03274	0.1707	-.00550	0.3182	0.430
87	11.15	-1.4290	.05583	0.8680	-.04744	0.2428	-.01196	0.4639	0.437
86	14.58	-1.7593	.09267	0.8000	-.06035	0.3010	-.02029	0.5955	0.447
85	17.80	-1.9929	.13311	0.7208	-.07123	0.3432	-.02994	0.7108	0.460
84	20.78	-2.1317	.17396	0.6349	-.07998	0.3688	-.04036	0.8092	0.475
83	23.50	-2.1856	.21265	0.5461	-.08668	0.3782	-.05106	0.8911	0.492
82	25.97	-2.1684	.24744	0.4576	-.09150	0.3731	-.06164	0.9579	0.512
81	28.17	-2.0957	.27734	0.3716	-.09468	0.3550	-.07180	1.0114	0.533
80	30.14	-1.9822	.30197	0.2900	-.09646	0.3262	-.08134	1.0534	0.556
78	33.39	-1.6821	.33598	0.1428	-.09679	0.2435	-.09812	1.1106	0.606
76	35.84	-1.3439	.35269	0.0187	-.09420	0.1386	-.11164	1.1424	0.661
74	37.63	-1.0110	.35657	-0.0834	-.08991	0.0213	-.12206	1.1581	0.720
72	38.86	-0.7039	.35166	-0.1667	-.08474	-0.1018	-.12978	1.1638	0.783
70	39.63	-0.4301	.34108	-0.2341	-.07923	-0.2265	-.13521	1.1631	0.849
65	40.07	0.1122	.30281	-0.3517	-.06560	-0.5307	-.14112	1.1437	1.027
60	39.01	0.4953	.26045	-0.4215	-.05352	-0.8124	-.13948	1.1025	1.222
55	36.96	0.7746	.22059	-0.4634	-.04333	-1.0670	-.13307	1.0321	1.435
50	34.24	0.9914	.18510	-0.4892	-.03489	-1.2946	-.12363	0.9190	1.669
45	31.02	1.1760	.15419	-0.5068	-.02797	-1.4977	-.11236	0.7450	1.926
40	27.41	1.3541	.12757	-0.5227	-.02237	-1.6824	-.10013	0.4860	2.210
35	23.45	1.5555	.10485	-0.5446	-.01791	-1.8639	-.08766	0.1078	2.526
30	19.17	1.8313	.08561	-0.5849	-.01444	-2.0823	-.07549	-0.4456	2.877
25	14.51	2.3049	.06947	-0.6731	-.01186	-2.4564	-.06403	-1.2948	3.270
20	09.31	3.4366	.05595	-0.9157	-.01010	-3.4544	-.05350	-2.8660	3.709

$M_1 = 5.00$ $\gamma = 1.4$

β^o	θ^o	F_1	F_2	F_3	F_4	F_5	F_6	F_7	M
90	00.00	0.0000	.00000	0.9667	.00000	0.0000	.00000	0.0000	0.415
89	03.99	-0.5598	.00728	0.9546	-.01674	0.0900	-.00146	0.1682	0.417
88	07.90	-1.0774	.02814	0.9194	-.03272	0.1740	-.00571	0.3303	0.422
87	11.68	-1.5179	.05995	0.8641	-.04728	0.2466	-.01238	0.4809	0.429
86	15.26	-1.8593	.09901	0.7929	-.05995	0.3041	-.02094	0.6162	0.440
85	18.60	-2.0935	.14143	0.7107	-.07047	0.3444	-.03079	0.7341	0.453
84	21.68	-2.2246	.18369	0.6222	-.07880	0.3672	-.04133	0.8341	0.469
83	24.48	-2.2650	.22314	0.5315	-.08503	0.3732	-.05207	0.9171	0.488
82	27.01	-2.2316	.25801	0.4418	-.08937	0.3641	-.06259	0.9845	0.508
81	29.26	-2.1417	.28742	0.3555	-.09207	0.3421	-.07261	1.0385	0.530
80	31.25	-2.0118	.31113	0.2741	-.09342	0.3092	-.08193	1.0812	0.554
78	34.53	-1.6844	.34252	0.1290	-.09303	0.2194	-.09813	1.1404	0.606
76	36.98	-1.3280	.35631	0.0084	-.08993	0.1086	-.11096	1.1758	0.663
74	38.74	-0.9847	.35749	-0.0898	-.08533	-0.0133	-.12068	1.1966	0.724
72	39.94	-0.6731	.35029	-0.1689	-.08001	-0.1398	-.12773	1.2087	0.789
70	40.68	-0.3989	.33789	-0.2323	-.07444	-0.2671	-.13255	1.2155	0.858
65	41.04	0.1358	.29675	-0.3410	-.06100	-0.5754	-.13724	1.2187	1.041
60	39.91	0.5064	.25310	-0.4033	-.04927	-0.8592	-.13475	1.2044	1.243
55	37.83	0.7720	.21278	-0.4386	-.03947	-1.1147	-.12774	1.1647	1.465
50	35.09	0.9741	.17723	-0.4579	-.03140	-1.3417	-.11789	1.0865	1.709
45	31.87	1.1415	.14645	-0.4684	-.02481	-1.5413	-.10634	0.9524	1.979
40	28.28	1.2973	.12007	-0.4756	-.01950	-1.7167	-.09394	0.7396	2.282
35	24.37	1.4659	.09762	-0.4855	-.01527	-1.8770	-.08136	0.4161	2.622
30	20.17	1.6857	.07870	-0.5066	-.01198	-2.0474	-.06917	-0.0671	3.006
25	15.64	2.0418	.06294	-0.5578	-.00952	-2.3046	-.05782	-0.8026	3.441
20	10.67	2.8144	.04995	-0.6980	-.00782	-2.9304	-.04757	-2.0544	3.933

$M_1 = 6.00$ $\gamma = 1.4$

β^o	θ^o	F_1	F_2	F_3	F_4	F_5	F_6	F_7	M
90	00.00	0.0000	.00000	0.9684	.00000	0.0000	.00000	0.0000	0.404
89	04.25	-0.6135	.00808	0.9553	-.01675	0.0928	-.00154	0.1773	0.406
88	08.42	-1.1762	.03115	0.9174	-.03267	0.1786	-.00601	0.3476	0.411
87	12.43	-1.6474	.06598	0.8581	-.04703	0.2517	-.01298	0.5049	0.419
86	16.21	-2.0027	.10821	0.7825	-.05934	0.3079	-.02185	0.6453	0.431
85	19.73	-2.2352	.15329	0.6960	-.06937	0.3454	-.03194	0.7667	0.445
84	22.94	-2.3527	.19735	0.6040	-.07709	0.3639	-.04263	0.8689	0.462
83	25.85	-2.3718	.23756	0.5107	-.08266	0.3648	-.05337	0.9532	0.482
82	28.45	-2.3136	.27225	0.4197	-.08634	0.3501	-.06377	1.0215	0.503
81	30.76	-2.1986	.30069	0.3331	-.08842	0.3224	-.07355	1.0763	0.527
80	32.78	-2.0453	.32285	0.2523	-.08919	0.2840	-.08254	1.1201	0.552
78	36.08	-1.6807	.35029	0.1106	-.08789	0.1844	-.09788	1.1828	0.607
76	38.51	-1.3007	.35994	-0.0051	-.08418	0.0656	-.10975	1.2239	0.667
74	40.23	-0.9449	.35743	-0.0977	-.07924	-0.0624	-.11851	1.2526	0.731
72	41.39	-0.6288	.34723	-0.1712	-.07377	-0.1937	-.12468	1.2744	0.799
70	42.08	-0.3550	.33249	-0.2293	-.06820	-0.3246	-.12870	1.2926	0.870
65	42.32	0.1676	.28782	-0.3264	-.05509	-0.6392	-.13183	1.3293	1.063
60	41.11	0.5211	.24270	-0.3793	-.04388	-0.9274	-.12826	1.3547	1.274
55	38.97	0.7685	.20194	-0.4064	-.03462	-1.1864	-.12051	1.3609	1.508
50	36.20	0.9515	.16642	-0.4179	-.02706	-1.4160	-.11015	1.3357	1.768
45	32.98	1.0973	.13589	-0.4199	-.02092	-1.6160	-.09825	1.2634	2.059
40	29.42	1.2257	.10985	-0.4171	-.01600	-1.7865	-.08561	1.1233	2.390
35	25.58	1.3552	.08778	-0.4134	-.01210	-1.9300	-.07289	0.8865	2.770
30	21.49	1.5110	.06927	-0.4141	-.00908	-2.0563	-.06066	0.5097	3.210
25	17.13	1.7423	.05395	-0.4289	-.00682	-2.2001	-.04936	-0.0791	3.724
20	12.44	2.1883	.04152	-0.4830	-.00522	-2.4907	-.03936	-1.0335	4.324

$M_1 = 7.00$ $\gamma = 1.4$

β^o	θ^o	F_1	F_2	F_3	F_4	F_5	F_6	F_7	M
90	00.00	0.0000	.00000	0.9694	.00000	0.0000	.00000	0.0000	0.397
89	04.43	-0.6499	.00863	0.9557	-.01676	0.0946	-.00159	0.1832	0.399
88	08.76	-1.2429	.03319	0.9159	-.03263	0.1816	-.00620	0.3589	0.404
87	12.92	-1.7339	.07005	0.8539	-.04685	0.2549	-.01336	0.5206	0.413
86	16.83	-2.0971	.11432	0.7754	-.05892	0.3102	-.02242	0.6642	0.425
85	20.45	-2.3269	.16106	0.6862	-.06862	0.3455	-.03266	0.7878	0.440
84	23.75	-2.4338	.20613	0.5920	-.07595	0.3611	-.04342	0.8913	0.458
83	26.73	-2.4377	.24667	0.4973	-.08111	0.3586	-.05414	0.9763	0.478
82	29.37	-2.3624	.28105	0.4055	-.08437	0.3402	-.06444	1.0453	0.500
81	31.71	-2.2306	.30869	0.3189	-.08607	0.3088	-.07404	1.1007	0.525
80	33.75	-2.0623	.32973	0.2387	-.08650	0.2669	-.08280	1.1453	0.551
78	37.05	-1.6744	.35446	0.0993	-.08467	0.1610	-.09757	1.2107	0.608
76	39.46	-1.2804	.36144	-0.0131	-.08063	0.0373	-.10882	1.2559	0.669
74	41.16	-0.9178	.35663	-0.1022	-.07551	-0.0945	-.11700	1.2902	0.736
72	42.28	-0.5997	.34462	-0.1722	-.06999	-0.2288	-.12262	1.3188	0.806
70	42.94	-0.3269	.32851	-0.2271	-.06445	-0.3621	-.12617	1.3446	0.879
65	43.11	0.1873	.28185	-0.3173	-.05158	-0.6811	-.12837	1.4041	1.077
60	41.84	0.5299	.23598	-0.3647	-.04072	-0.9730	-.12417	1.4565	1.295
55	39.67	0.7663	.19503	-0.3871	-.03181	-1.2358	-.11600	1.4944	1.537
50	36.88	0.9380	.15960	-0.3941	-.02456	-1.4693	-.10534	1.5065	1.808
45	33.65	1.0711	.12927	-0.3915	-.01871	-1.6730	-.09323	1.4788	2.114
40	30.11	1.1837	.10346	-0.3832	-.01403	-1.8457	-.08045	1.3926	2.465
35	26.31	1.2914	.08163	-0.3724	-.01034	-1.9869	-.06764	1.2218	2.875
30	22.28	1.4128	.06335	-0.3629	-.00750	-2.0992	-.05536	0.9265	3.360
25	18.04	1.5811	.04827	-0.3608	-.00538	-2.1977	-.04408	0.4419	3.941
20	13.52	1.8815	.03612	-0.3800	-.00388	-2.3494	-.03416	-0.3542	4.641

$M_1 = 8.00$ $\gamma = 1.4$

β^o	θ^o	F_1	F_2	F_3	F_4	F_5	F_6	F_7	M
90	00.00	0.0000	.00000	0.9701	.00000	0.0000	.00000	0.0000	0.393
89	04.55	-0.6755	.00902	0.9558	-.01677	0.0958	-.00163	0.1873	0.395
88	09.00	-1.2895	.03463	0.9148	-.03260	0.1836	-.00633	0.3666	0.400
87	13.26	-1.7939	.07288	0.8510	-.04672	0.2570	-.01362	0.5313	0.409
86	17.26	-2.1620	.11854	0.7704	-.05863	0.3115	-.02281	0.6771	0.422
85	20.95	-2.3891	.16636	0.6794	-.06810	0.3454	-.03314	0.8020	0.437
84	24.30	-2.4879	.21206	0.5837	-.07516	0.3590	-.04393	0.9064	0.455
83	27.32	-2.4808	.25274	0.4881	-.08004	0.3540	-.05463	0.9919	0.476
82	29.99	-2.3935	.28682	0.3959	-.08303	0.3331	-.06485	1.0613	0.499
81	32.34	-2.2503	.31385	0.3094	-.08448	0.2992	-.07433	1.1172	0.524
80	34.39	-2.0717	.33407	0.2296	-.08469	0.2549	-.08292	1.1624	0.550
78	37.70	-1.6685	.35693	0.0919	-.08253	0.1449	-.09731	1.2298	0.608
76	40.10	-1.2655	.36210	-0.0183	-.07829	0.0179	-.10814	1.2781	0.672
74	41.77	-0.8989	.35579	-0.1050	-.07308	-0.1165	-.11593	1.3163	0.739
72	42.87	-0.5798	.34259	-0.1727	-.06754	-0.2527	-.12120	1.3497	0.810
70	43.51	-0.3080	.32562	-0.2255	-.06202	-0.3876	-.12443	1.3810	0.885
65	43.62	0.2003	.27774	-0.3113	-.04934	-0.7099	-.12605	1.4565	1.087
60	42.32	0.5357	.23143	-0.3552	-.03871	-1.0047	-.12145	1.5279	1.310
55	40.12	0.7648	.19041	-0.3747	-.03003	-1.2708	-.11300	1.5882	1.558
50	37.32	0.9292	.15506	-0.3789	-.02299	-1.5080	-.10216	1.6272	1.836
45	34.09	1.0542	.12487	-0.3734	-.01733	-1.7157	-.08992	1.6322	2.153
40	30.56	1.1569	.09922	-0.3617	-.01281	-1.8925	-.07705	1.5867	2.519
35	26.78	1.2511	.07755	-0.3467	-.00927	-2.0364	-.06418	1.4669	2.952
30	22.80	1.3516	.05942	-0.3313	-.00655	-2.1464	-.05187	1.2366	3.471
25	18.63	1.4831	.04449	-0.3198	-.00453	-2.2275	-.04057	0.8351	4.107
20	14.22	1.7040	.03250	-0.3213	-.00311	-2.3144	-.03070	0.1529	4.896

$M_1 = 9.00$ $\gamma = 1.4$

β^o	θ^o	F_1	F_2	F_3	F_4	F_5	F_6	F_7	M
90	00.00	0.0000	.00000	0.9705	.00000	0.0000	.00000	0.0000	0.390
89	04.63	-0.6939	.00930	0.9560	-.01677	0.0967	-.00165	0.1902	0.392
88	09.16	-1.3230	.03566	0.9139	-.03258	0.1851	-.00643	0.3721	0.397
87	13.49	-1.8369	.07491	0.8489	-.04663	0.2585	-.01381	0.5389	0.407
86	17.56	-2.2081	.12155	0.7669	-.05842	0.3124	-.02308	0.6861	0.419
85	21.30	-2.4330	.17013	0.6746	-.06772	0.3452	-.03347	0.8120	0.435
84	24.69	-2.5257	.21624	0.5779	-.07460	0.3573	-.04428	0.9170	0.453
83	27.73	-2.5105	.25696	0.4816	-.07928	0.3506	-.05496	1.0029	0.475
82	30.42	-2.4146	.29080	0.3892	-.08209	0.3279	-.06512	1.0726	0.498
81	32.79	-2.2631	.31737	0.3027	-.08336	0.2922	-.07450	1.1289	0.523
80	34.85	-2.0774	.33698	0.2233	-.08342	0.2463	-.08298	1.1745	0.550
78	38.15	-1.6636	.35849	0.0868	-.08104	0.1334	-.09709	1.2435	0.609
76	40.54	-1.2546	.36240	-0.0218	-.07667	0.0041	-.10764	1.2940	0.673
74	42.20	-0.8853	.35505	-0.1068	-.07140	-0.1321	-.11515	1.3351	0.742
72	43.28	-0.5657	.34106	-0.1730	-.06585	-0.2697	-.12018	1.3720	0.814
70	43.90	-0.2947	.32349	-0.2243	-.06036	-0.4058	-.12321	1.4072	0.889
65	43.98	0.2093	.27481	-0.3071	-.04781	-0.7304	-.12442	1.4942	1.094
60	42.65	0.5396	.22822	-0.3487	-.03735	-1.0275	-.11955	1.5794	1.320
55	40.43	0.7638	.18717	-0.3661	-.02883	-1.2962	-.11092	1.6561	1.572
50	37.62	0.9231	.15189	-0.3685	-.02194	-1.5365	-.09996	1.7150	1.856
45	34.39	1.0427	.12181	-0.3611	-.01641	-1.7479	-.08763	1.7445	2.181
40	30.87	1.1388	.09627	-0.3473	-.01201	-1.9289	-.07469	1.7300	2.559
35	27.11	1.2239	.07471	-0.3295	-.00856	-2.0770	-.06178	1.6501	3.008
30	23.16	1.3107	.05669	-0.3104	-.00593	-2.1893	-.04944	1.4719	3.555
25	19.03	1.4186	.04186	-0.2932	-.00399	-2.2654	-.03814	1.1391	4.236
20	14.71	1.5908	.02996	-0.2843	-.00262	-2.3215	-.02828	0.5492	5.101

$M_1 = 10.00$ $\gamma = 1.4$

β^o	θ^o	F_1	F_2	F_3	F_4	F_5	F_6	F_7	M
90	00.00	0.0000	.00000	0.9708	.00000	0.0000	.00000	0.0000	0.388
89	04.70	-0.7076	.00951	0.9560	-.01677	0.0973	-.00167	0.1923	0.390
88	09.28	-1.3479	.03643	0.9133	-.03256	0.1861	-.00650	0.3761	0.395
87	13.67	-1.8686	.07642	0.8473	-.04656	0.2595	-.01394	0.5444	0.405
86	17.78	-2.2419	.12377	0.7642	-.05826	0.3131	-.02327	0.6928	0.417
85	21.55	-2.4650	.17288	0.6710	-.06745	0.3451	-.03371	0.8194	0.433
84	24.98	-2.5531	.21927	0.5736	-.07419	0.3560	-.04453	0.9248	0.452
83	28.03	-2.5318	.26002	0.4769	-.07873	0.3481	-.05520	1.0110	0.474
82	30.74	-2.4295	.29366	0.3843	-.08140	0.3241	-.06531	1.0808	0.497
81	33.11	-2.2720	.31986	0.2979	-.08254	0.2871	-.07462	1.1374	0.523
80	35.17	-2.0810	.33903	0.2188	-.08250	0.2399	-.08301	1.1834	0.550
78	38.47	-1.6596	.35935	0.0832	-.07996	0.1249	-.09691	1.2535	0.610
76	40.86	-1.2464	.36254	-0.0243	-.07551	-0.0060	-.10726	1.3057	0.674
74	42.50	-0.8753	.35444	-0.1081	-.07020	-0.1435	-.11457	1.3490	0.743
72	43.57	-0.5555	.33988	-0.1731	-.06465	-0.2821	-.11943	1.3885	0.816
70	44.18	-0.2850	.32190	-0.2234	-.05918	-0.4190	-.12231	1.4266	0.893
65	44.23	0.2158	.27266	-0.3041	-.04673	-0.7454	-.12323	1.5222	1.099
60	42.89	0.5424	.22589	-0.3440	-.03639	-1.0443	-.11818	1.6176	1.328
55	40.65	0.7630	.18483	-0.3600	-.02799	-1.3151	-.10942	1.7066	1.583
50	37.84	0.9188	.14960	-0.3611	-.02120	-1.5580	-.09837	1.7804	1.871
45	34.61	1.0345	.11960	-0.3524	-.01576	-1.7726	-.08598	1.8287	2.201
40	31.09	1.1259	.09414	-0.3370	-.01144	-1.9574	-.07300	1.8381	2.588
35	27.34	1.2047	.07266	-0.3174	-.00807	-2.1099	-.06006	1.7898	3.051
30	23.41	1.2821	.05471	-0.2957	-.00551	-2.2262	-.04770	1.6536	3.620
25	19.32	1.3738	.03995	-0.2747	-.00362	-2.3029	-.03639	1.3780	4.337
20	15.05	1.5136	.02812	-0.2592	-.00230	-2.3453	-.02653	0.8664	5.267

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